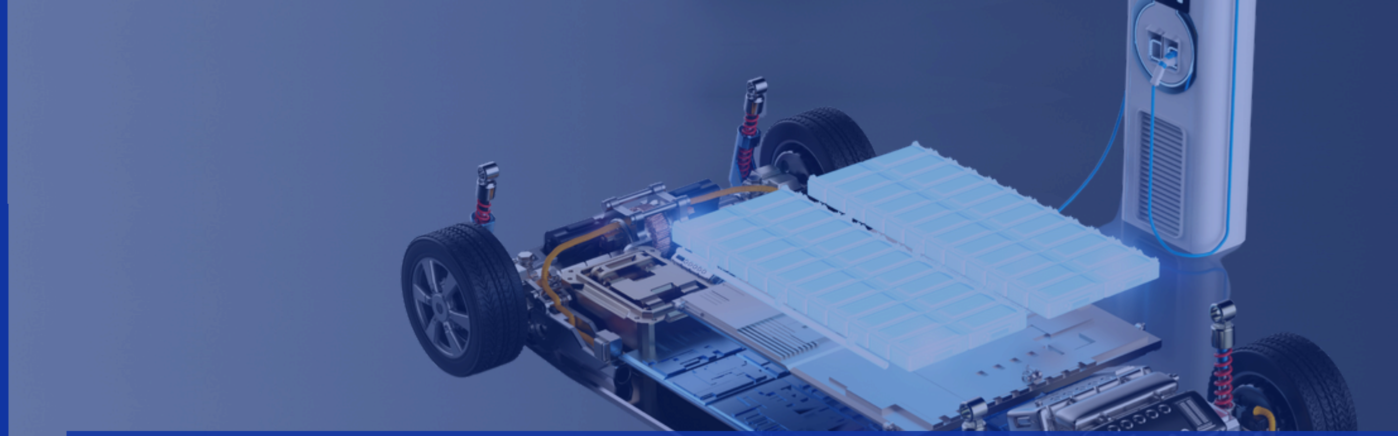
H.B. Fuller®

OPTIMIZING THERMAL MANAGEMENT IN EV POWER STORAGE FOR SAFER, STRONGER BATTERIES



WELL-BEHAVED ELECTRIC VEHICLE BATTERIES SELDOM MAKE NEWS

Grainy video footage shows a Tesla Model S parked in an underground parking lot. The undercarriage starts steaming, and within seconds, the entire car bursts into flame, obscuring the camera.

This kind of footage grabs consumer interest and media attention, but in reality, electric vehicle (EV) battery fires are rare. Although Tesla has sold over a million EVs in the last fifteen years, only 232 fires have been confirmed.[i],[ii] Also, a recent third-party data analysis of US national databases found that EVs are less likely to catch on fire than combustion engines and hybrid vehicles.[iii]

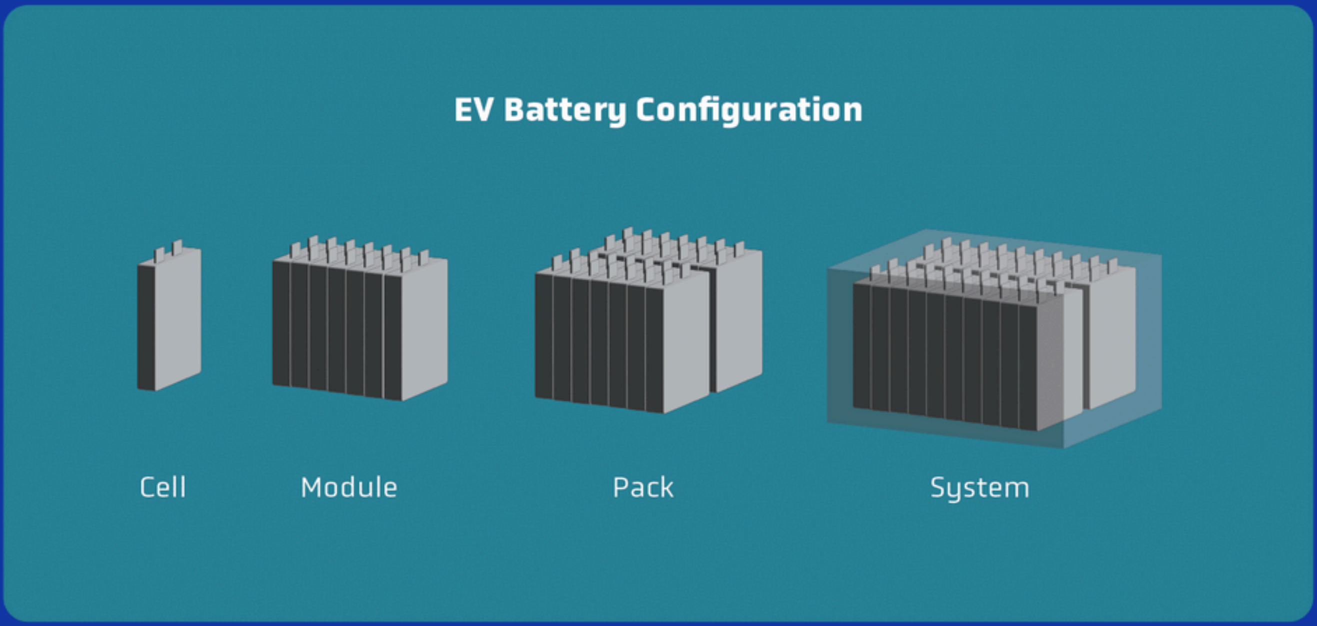
The danger of EVs catching fire is real, but the actual number of fires is limited by the thermal management solutions used in EV battery systems. Thermal interface materials, foam encapsulants, dielectric coatings, and more work in harmony to ensure heat is managed safely. Innovative thermal management solutions working together also optimize battery performance so EVs can go further and last longer. Smart EV battery systems are better for consumers, manufacturers, and, ultimately, the environment.

CONTENTS

WHY THERMAL MANAGEMENT IS CRUCIAL TO EV BATTERIES

Comprehensive thermal management solutions play a critical role in EV battery systems because of the electrochemical makeup of commonly used lithium-ion (Li-ion) cells. EV battery systems are packs of modules composed of individual Li-ion cells (Figure 1).

Figure 1. EV battery assembly example [taken from https://www.quantumscape.com/blog/ev-battery-cell-formats-for-lithium-metal/]



Li-ion batteries have the winning combination of high energy density, prolonged life cycle, and rapid charge and discharge rates to power an entire vehicle for hundreds of miles.[i] However, their unique electrochemical formulation generates more heat than other types of batteries. The electrolyte solution, which allows electrical charges to flow through the battery, is made from highly flammable organic compounds.[ii] Thermal runaway within Li-ion batteries can result in long-lasting fires that are difficult to extinguish.[iii]

Li-ion batteries are highly affected by temperature. When temperatures drop below 0°C, the batteries age faster, which shortens their effectiveness. Temperatures below -10°C cause power and energy loss, and temperatures below -40°C can cause battery failure. High temperatures accelerate aging, reduce power capacity, and can cause thermal runaway events leading to fires. Extreme temperature fluctuations can also accelerate thermal aging.[iv]

Thermal management solutions are necessary to dissipate the heat generated during regular battery use and isolate overheating cells. They also provide structural support for battery assemblies, prevent uneven cell aging, and insulate battery components from electric arcing. Li-ion EV batteries would be unreliable, unstable, and unsafe without thermal management.

THE THERMAL MANAGEMENT SOLUTIONS ECOSYSTEM

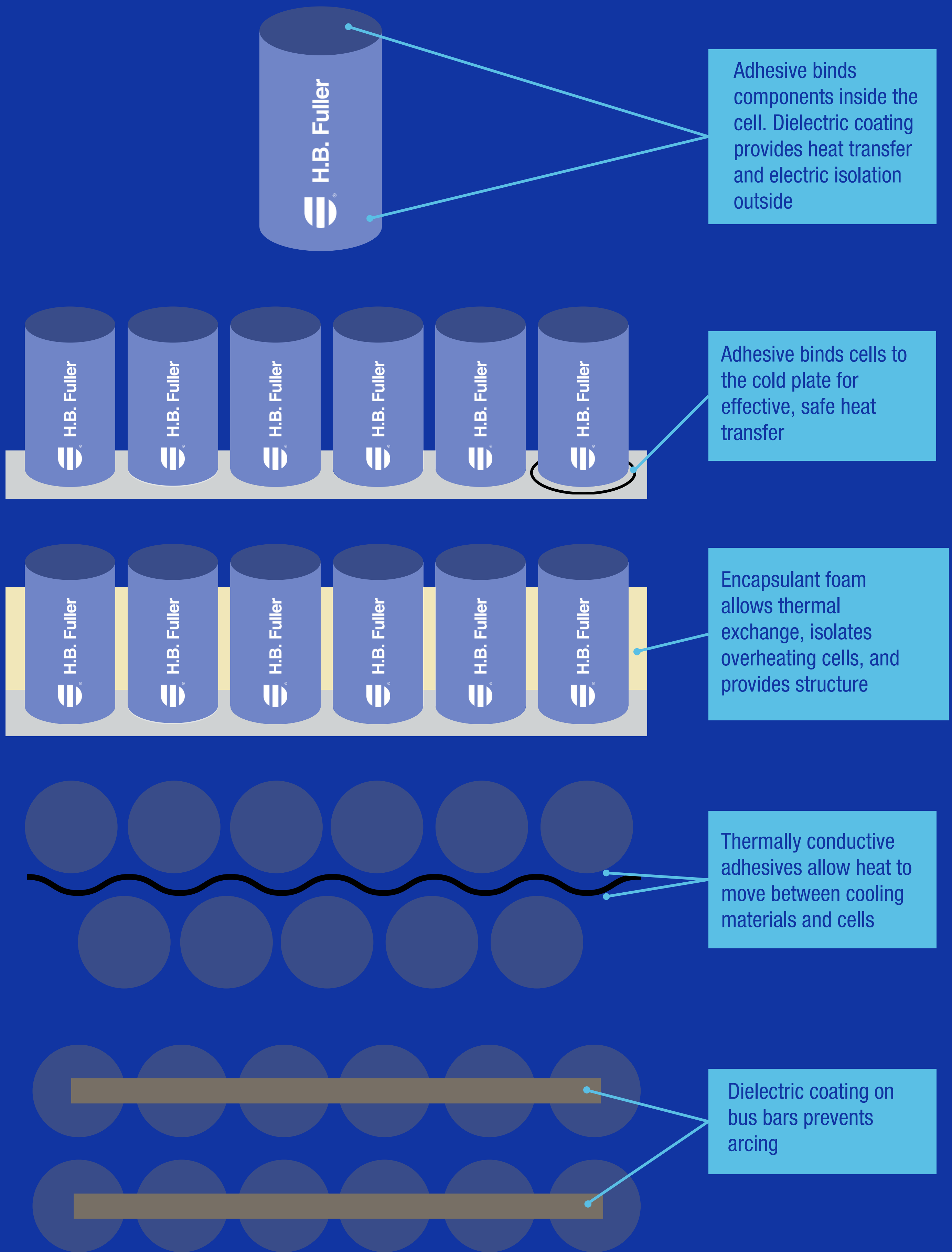
Integrating multiple thermal management solutions in an EV battery pack ensures it stays safe and functions at its best (Figure 2). Encapsulant materials, thermal interface materials (TIMs), thermal conductive adhesives (TCAs), and dielectric coatings contribute to effective heat exchange, electrical isolation, and structural stability.

Dr. Marlen Valverde, Business Development Manager of Global Strategic OEM/EV at H.B. Fuller, explains:

"You want to keep the EV battery working in an extremely safe temperature range—far away from the ignition point of the liquid electrolyte. No single adhesive or coating is the solution. It's part of a whole effort, a push, to improve thermal management."

- Dr. Marlen Valverde
Business Development Manager of Global Strategic OEM/EV, H.B. Fuller

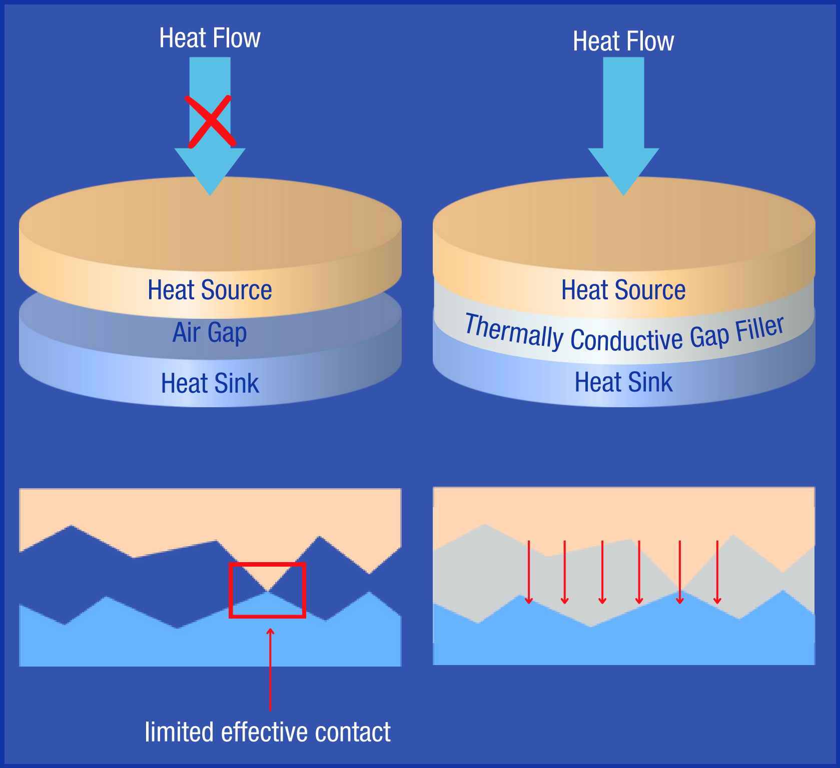
Figure 2. Thermal management solutions for EV batteries with cylindrical cells



THERMALLY CONDUCTIVE ADHESIVES TRANSFER HEAT, ISOLATE ELECTRICITY

TIMs dissipate heat naturally generated by the Li-ion battery cells within EV battery systems. TIMs provide a thermally conductive layer between two materials, such as a cylindrical Li-ion battery cell and a cooling plate. These materials should not touch but need a way to transfer heat effectively. Using TIMs in gaps between heat sources and heat sinks enables a higher and more efficient heat flow (Figure 3).

Figure 3. Thermal interface materials improve heat flow



Most TIMs have additional uses besides passing heat from cells to heat sinks. TCAs, for example, also have dielectric properties and serve to bond material together and provide structural support. Dielectric means that they keep electric charges from passing between surfaces. Because EV batteries must have structural integrity and bonded strength to withstand the wear and tear of being on the road, using TCAs as TIMs is a natural choice.

TCAs adhere to a wide variety of substrates, including metals, thermosets, and thermoplastics, and work to move heat from cells to cooling plates or other cooling mechanisms within the battery pack. TCAs bond many components within a battery assembly, including:

- Prismatic cells to other prismatic cells
- Pouch cells to cold plates
- Cylindrical cells to cell carriers
- Cooling grievances running between cells
- Cells to side walls
- Cold plates to the bottom of subsequent modules
- Cylindrical cells to cold plates (Figure 4)

Figure 4. Example of thermally conductive adhesives bonding cylindrical cells to a cold plate

PRODUCT HIGHLIGHT

EV THERM 441

DESCRIPTION: This modified, highly engineered structural acrylic adhesive provides excellent thermal conductivity while maintaining superior strength and performance properties across a wide range of temperatures and substrates.

EV Therm 441 is also a flame retardant with a UL94 V0 rating and allows control of the adhesive gap to a diameter of 0.25 mm (0.01 in).

RECOMMENDED FOR: metals (e.g., steel), thermoplastics (e.g., polycarbonate), and thermosets (e.g., fiberglass).

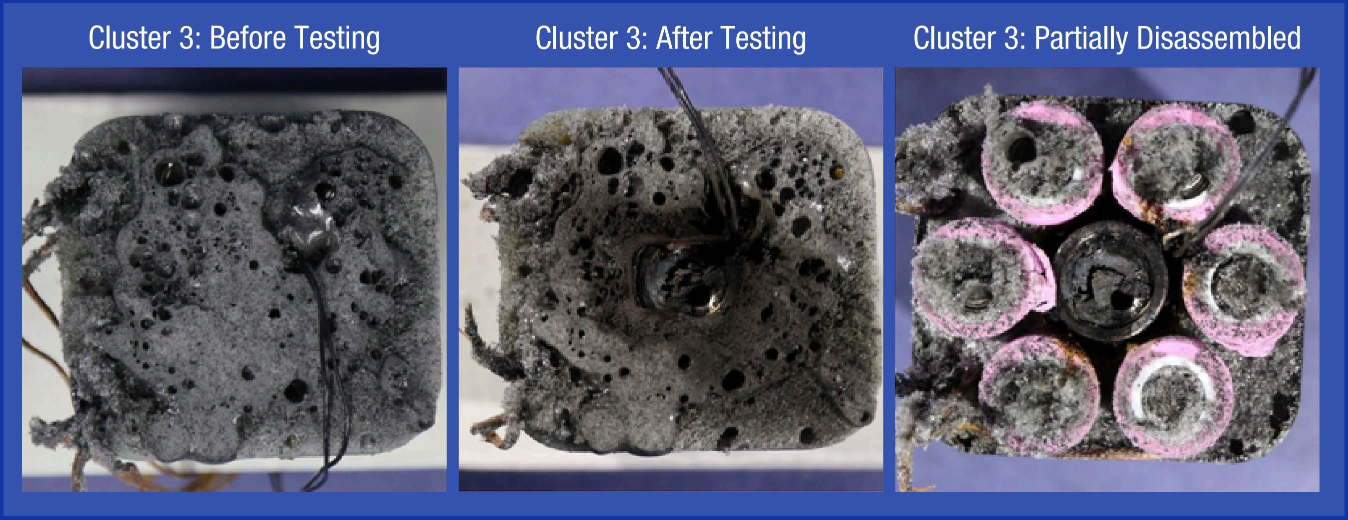
ADDITIONAL FEATURES AND BENEFITS: No surface preparation required, high impact resistance, easy manual and pneumatic dispensing, 100% reactive, room temperature cure, 10:1 meter-mix product for ease of application, low odor, low exotherm.

ENCAPSULANTS ISOLATE HEAT EVENTS, PROVIDE STRUCTURE

Fires in Li-ion battery packs are rare but possible. When the battery short-circuits, overheats, or gets damaged in a collision, thermal runaway can spiral into electrolyte combustion and fires or explosions. Unlike other types of fires, Li-ion battery fires cannot be suffocated or put out by water and burn for a long period. [vii] Encapsulants play an important part in thermal management by stopping fires before they spread to other Li-ion cells and keeping battery components in place upon impact.

H.B. Fuller's proprietary, UL94 V0-rated polyurethane (PU) foam encapsulant is the first of its kind. When an individual battery cell is exposed to an open flame, the encapsulant keeps the fire from spreading to other cells. Figure 5 shows a cluster of cylindrical Li-ion battery cells encased in foam encapsulant before and after inducing thermal runaway in the center-most cell. Removing the encapsulant material reveals how well the fire in the central cell was isolated from the surrounding cells.

Figure 5. H.B. Fuller's patented foam encapsulant prevents fires from spreading between battery cells

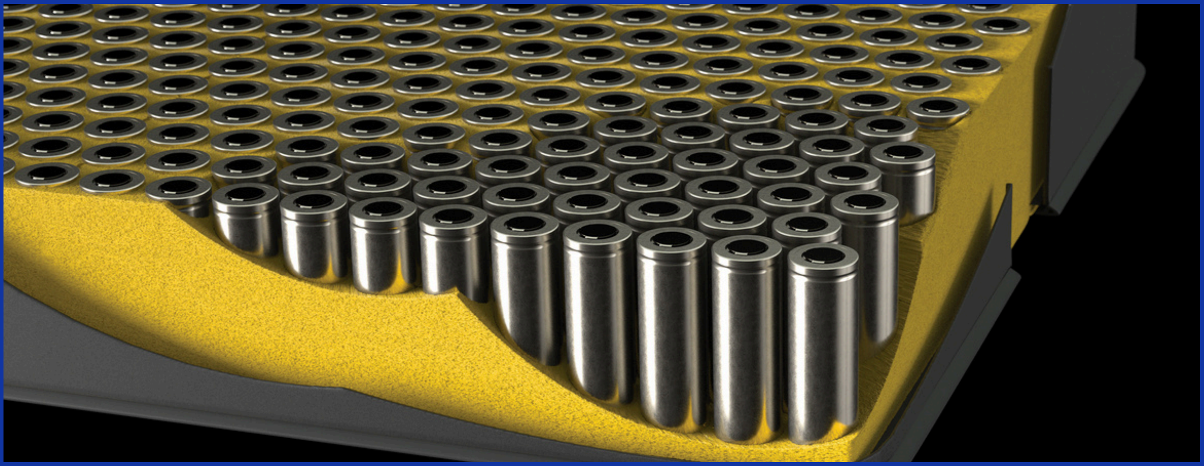


Fires may also break out during extreme impacts, like crashes. Damage to the battery system can threaten the assembly's thermal stability. For example, if two metal components typically separated by a TIM pad shake free from their protective layer and make close contact, the heat could build quickly and start a fire. Encapsulants' semi-structural and impact-resistant properties hold battery components in place during a collision, lessening the possibility of thermal runaway initiated by undesired interactions between loose components.

Encapsulants may also play an important role in unitizing the battery assembly and protecting cells from corrosion by creating an effective barrier to the coolant solution or moisture that could be present inside a battery pack.

The encapsulant is dispensed around battery cells during assembly (Figure 6). Once it has cured, its unitizing properties also work towards maintaining a more homogeneous temperature range environment, dissipating the energy generated by the cells and ensuring a consistent internal temperature. The encapsulant also protects battery components from external environmental hazards like road salt or moisture that might penetrate the outer layers of the pack.

Figure 6. Foam encapsulant used to pot cells also unitizes battery packs

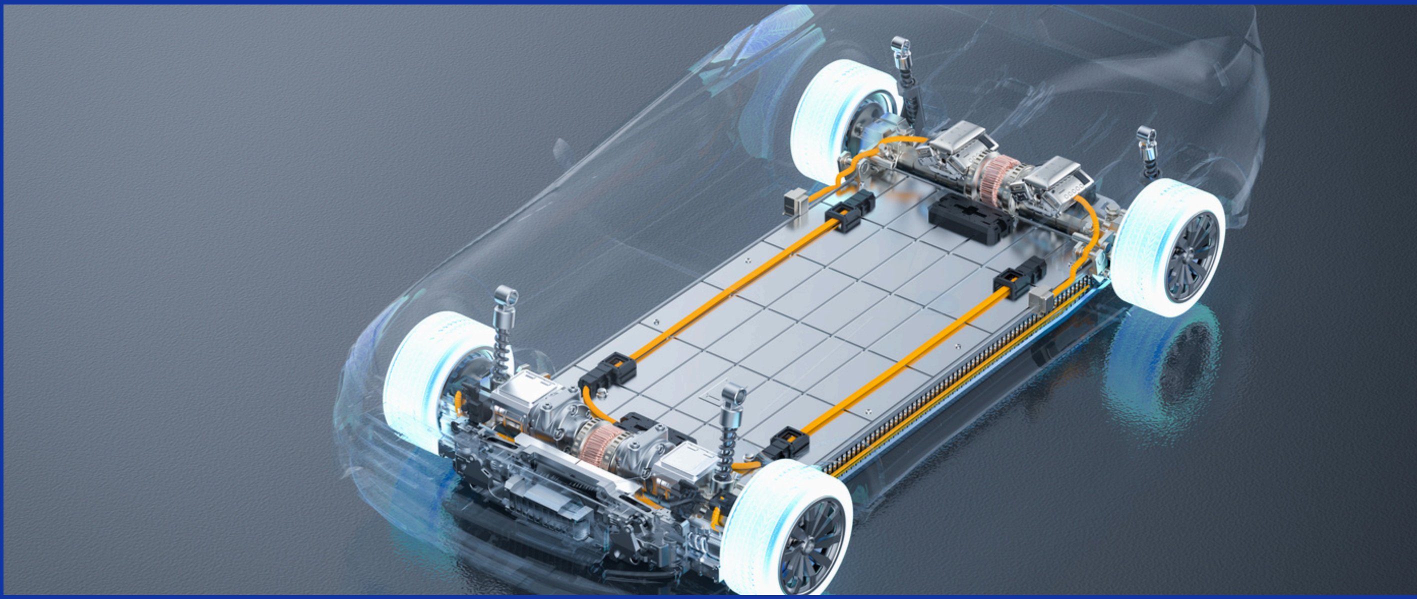


H.B. Fuller's encapsulant's unique benefits can optimize the life and use of EV battery systems. The encapsulant is lightweight compared with alternative materials (1.33 pounds/gallon compared to 12.51 pounds/gallon). Less weight from the battery pack increases an EV's range. The encapsulant also has a fast dispense, cure, and cycle time. Because it expands five times its liquid state, H.B. Fuller's encapsulant requires less material than alternatives, reducing shipping and material handling costs.

Table 1 compares the properties of H.B. Fuller's specialized foam encapsulant with those of alternative products. "Y" means yes, the material meets the property. "N" means no, the material does not meet the property, and "≈" means the material moderately meets the property.

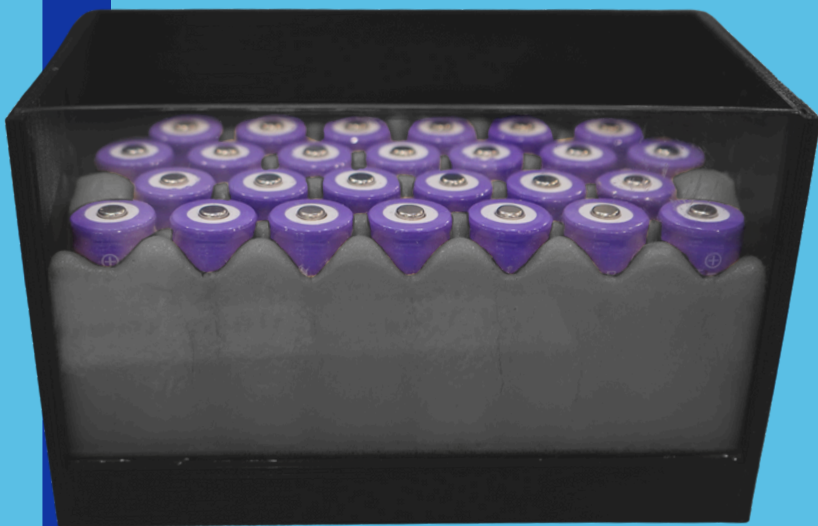
Table 1. Battery encapsulation comparison chart

Properties of a Good Encapsulant	Specialized PU Foam	Epoxy Foam	Solid Epoxy	Silicone Foam	Solid Silicone
No Outgassing	Y	N	Y	N	N
Low Initial Viscosity (cP)	Y	≈	≈	≈	N
Light Weight (kg/m3)	Y	≈	N	≈	N
Flame Retardancy	Y	Y	Y	Y	Y
Shock and Vibration	Y	Y	N	Y	≈
Contamination Concerns	Y	Y	Y	N	N
Cost	Y	≈	N	≈	N
Impact Resistance	Y	≈	N	Y	Y
Low Exotherm	Y	≈	N	Y	Y



PRODUCT HIGHLIGHT

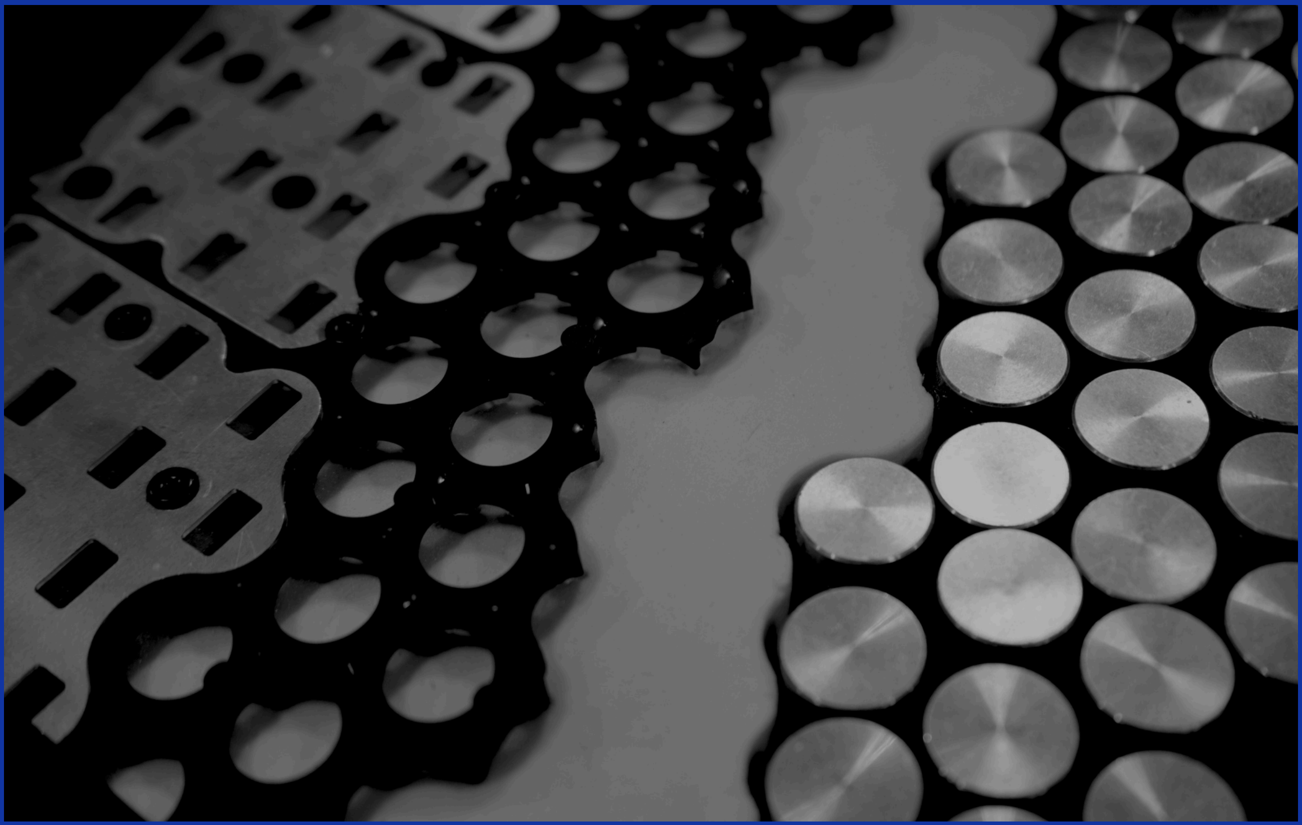
H.B. Fuller® EV PROTECT™ 5006



DESCRIPTION: This liquid-applied, two-component flame retardant, low-density polyurethane foam material is designed for potting and encapsulation of battery cells in EV battery modules. The product offers design engineers the ability to increase module power density while enhancing safety and protection from thermal propagation.

SPECIAL FEATURES: Ultra lightweight to minimize weight impact on battery modules; semi-structural properties provide noise, vibration, and harshness benefits by unitizing the module and absorbing external environmental impacts.

ADDITIONAL FEATURES AND BENEFITS: Low viscosity and self leveling, outstanding insulation properties, no outgassing during curing, meets UL94 V0 certification, up to 5x expansion rate, cost-effective because of low volume usage, dielectric properties, and fast processability.



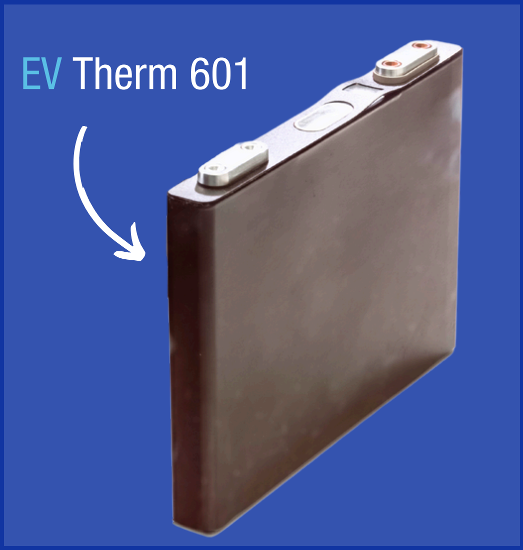
DIELECTRIC COATINGS CONTROL ELECTRICAL ACTIVITY, EXCHANGE HEAT

Dielectric coatings that isolate electrical activity and transmit heat are essential to the thermal management solutions ecosystem. Choosing dielectric coatings with thermal conductivity helps maintain an optimal operating temperature range while preventing arcing between components.

Dielectric coatings can be used to cover any surface in an EV battery assembly requiring electrical isolation, such as:

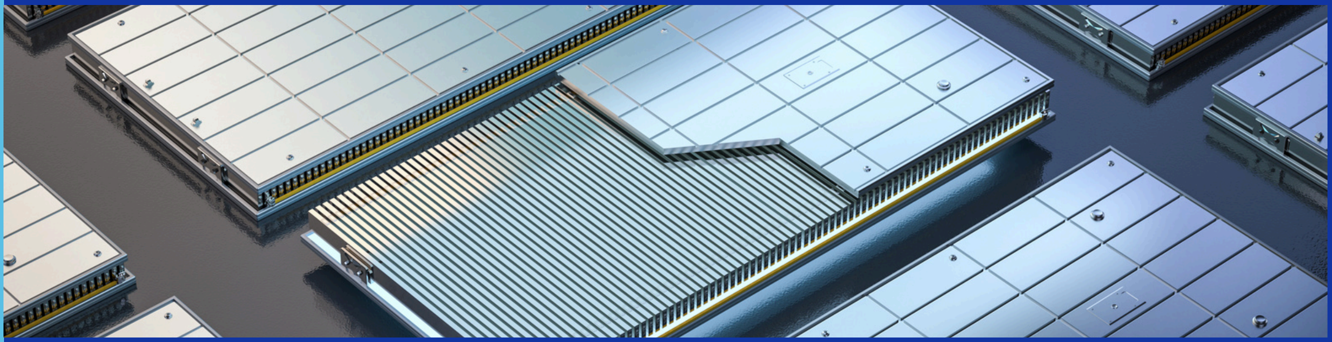
- Cooling plates
- Cooling grievances running between battery cells
- Bus bars
- Metal walls and wires
- Individual prismatic cells (Figure 7)

Figure 7. Dielectric coatings isolate electricity and dissipate heat from prismatic cells

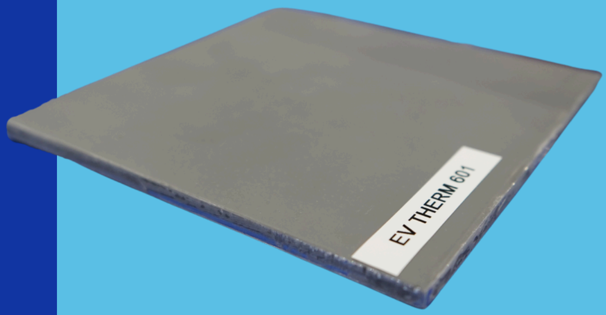


Manufacturers typically apply dielectric coatings via spray or powder. Both options have benefits, but spray coating has the advantage of low viscosity. Because the material used in dielectric spray coatings flows easily in its uncured state, spray coatings can be applied autonomously via a robot or spray head mounted to an assembly line. This improves manufacturing efficiency, reduces energy and labor costs, and can be done in-house. Dielectric spray coating also fills imperfections during application, reducing the need to scrap parts.

Some dielectric coatings, such as H.B. Fuller's EV Therm 601, use anti-scratch technology to maintain an even coating despite contact with other battery components. Sharp components can't break through the coating, ensuring it continues to provide electrical isolation and thermal management. EV Therm 601 can also be reworked without removing the original coating. In comparison, defects in powder coatings require time-consuming coating removal and re-coating or, in some cases, may lead to the part being scrapped.



PRODUCT HIGHLIGHT



EV THERM 601

DESCRIPTION: The EV Therm 601 dielectric, sprayable coating provides a minimum coating thickness of 150 microns and encapsulation protection for electronic assemblies and components. Because this material is designed to be thermally conductive, recommended uses include heatsinks, heat spreaders, cold plates, cooling tubes, and other thermal dissipation applications.

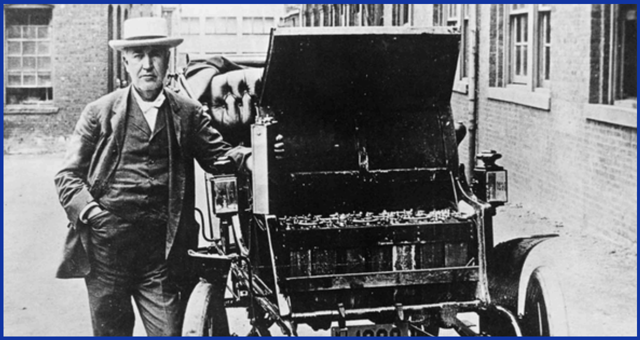
CURING: at room temperature using ultraviolet (UVA) light from metal halide, mercury, or LED lamps with a minimum energy of 1,000 mJ/cm2. Depending on the UVA light intensity, cure speed can be less than one minute.

FEATURES AND BENEFITS: One-component system for ease of application, low viscosity and surface tension for ease of dispensing, high dielectric strength, adhesion to metals and plastics without primers, superior low- and high-temperature cycling performance, meets UL94 V0 flammability requirements.

HOW INNOVATIONS DRIVE THE EV INDUSTRY

Although the first electric vehicles were on roads in the 1800s, their popularity has ebbed and flowed over the years with changing gas prices, technological innovations (and limitations), and growing clean energy legislation. It wasn't until the 21st century, with the global release of the Toyota Prius and the formation of Tesla, that electric vehicles experienced a revival. Technological innovations in EV batteries have played an enormous part in advancing the industry, as they directly influence EV cost and performance.[ix]

Figure 8. Electric vehicles in the 1800s vs. 2024
[images: https://rarehistoricalphotos.com/electric-cars-history-pictures-1880-1920/, https://www.caranddriver.com/reviews/a46788612/2024-honda-prologue-ev-drive/]



ADHESIVE SOLUTIONS FOR HIGH-DENSITY BATTERIES

One of the big challenges with EV batteries is extending the vehicle's range between charges. Batteries must be powerful and light to support long-distance trips but still cost-effective to manufacture and sell at a price consumers will pay.

Engineers have recently been experimenting with high-density batteries to meet consumer demands for EVs with higher ranges. Whereas typical EV battery packs contain stacks of modules containing cells, high-density EV packs contain cells positioned tightly within a single module to occupy as much space as possible.

Removing the supportive layers of cold plates and cell holders may allow more energy-dense batteries but also reduce the battery's structural integrity. Batteries must have the structural support to withstand being shaken by everyday use on the road. High-density batteries are not commercially viable without something to hold them in place.

H.B. Fuller's family of foam encapsulants, EV Protect, provides the structure and thermal management solutions to make high-density batteries a reality. EV Protect solutions have structural or semi-structural properties that hold cells safely in place during use without additional support layers. The ePower team developed, built, and tested the encapsulant foam specifically to meet the growing demand for structure in EV batteries.

ANTICIPATION AS A COMPETITIVE ADVANTAGE

As EV batteries continue to evolve to safely meet consumer needs, thermal management solution providers will continue to have to adapt to and anticipate changes. Foresight is key to remaining competitive in this agile industry.

To anticipate trends rather than adapt to them, the H.B. Fuller ePower team actively looks for gaps in the solutions currently offered to the market. They also seek information about manufacturers' problems with adhesives and what questions they are asking. By doing research, the team stays ahead of the curve in developing and testing new materials (Figure 9).

Figure 9. Process of developing solutions to tomorrow's EV challenges

H.B. Fuller also has a mature internal testing capacity to support the development of new thermal management solutions. Innovative materials need to be safe and reliable, and having the capacity to run tests according to industry standards is essential to creating materials that withstand flames, bumps, and even collisions.

Because members of the H.B. Fuller team understand both adhesives and EV battery assemblies, they can help identify the critical-to-quality properties that engineers need for batteries—like dielectric strength, bond strength, thermal resistance, and moisture resistance. Understanding how it all works together is key to creating battery packs that can go the distance.

> “We end up being experts. In my case, I can glue you a car. That’s how you best support the needs of your customers. It’s true not just for me but for everyone who works at H.B. Fuller. We look at the environment—at all influencing factors—and incorporate it seamlessly into the material's performance.”

- Dr. Marlen Valverde
Business Development Manager of Global Strategic OEM/EV, H.B. Fuller

THERMAL MANAGEMENT SOLUTIONS IN EV BATTERIES: AN ONGOING NEED

Emerging research on a solid-state alternative is the newest solution to the hazards posed by the electrochemical composition of Li-ion batteries. Instead of relying on electrolytes, solid-state EV batteries use lithium metal anodes to enable electrical charges to pass through the battery.[x] Solid-state batteries hold promise because they are less flammable than conventional Li-ion batteries and can be more compact. However, much more research is necessary before solid-state batteries become commercially feasible.[xi]

Although solid-state batteries may reduce fire risks for electric vehicles, they do not eliminate the need for thermal management in the battery or the other functions thermal management solutions provide, such as isolating electric currents and providing structural support. No matter what technological breakthroughs occur, an ecosystem of thermal management adhesives and coatings will always be needed in EV batteries.

PARTNERING WITH H.B. FULLER FOR THERMAL MANAGEMENT SOLUTIONS

H.B. Fuller is prepared to help EV manufacturers with the latest adhesive and sealant technology, providing turnkey solutions to improve the reliability and safety of battery packs. As the technology in this industry evolves, EV manufacturers won't just need solutions proven to work—they'll need a solution partner willing to innovate and break boundaries.

At H.B. Fuller, we thrive on solving your electric vehicle adhesive challenges. Contact a specialist to [learn more about available products or teaming with our scientists to create something new].

H.B. Fuller | Connecting what matters.™

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